Check List the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 19 (2): 147–153
https://doi.org/10.15560/19.2.147

PENSOFT.

Updated distribution of the Indo-Pacific Slender Gecko, *Hemiphyllodactylus typus* Bleeker, 1860 (Squamata, Gekkonidae), in Peninsular Malaysia and a discussion of its range expansion

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Abstract. *Hemiphyllodactylus typus* Bleeker, 1860 is a small, nocturnal, scansorial, unisexual gecko having a wide distribution throughout the archipelagos of the Indian and Pacific Oceans. In Peninsular Malaysia, it was previously reported from seven localities. Since then, *H. typus* has been reported from several new localities based on observations from recent field surveys. The updated distribution records of *H. typus* in Peninsular Malaysia are compiled here, where it is now known from 18 localities.

Keywords. Herpetofauna, reptiles, unisexual species

Academic editor: Perry L. Wood, Jr.
Received 5 December 2022, accepted 20 February 2023, published 3 March 2023

Hong Z, Anuar S, Zou B, Grismer LL, Quah ESH (2023) Updated distribution of the Indo-Pacific Slender Gecko, *Hemiphyllodactylus typus* Bleeker, 1860 (Squamata, Gekkonidae), in Peninsular Malaysia and a discussion of its range expansion. Check List 19 (2): 147–153. https://doi.org/10.15560/19.2.147

Introduction

Hemiphyllodactylus Bleeker, 1860 is a group of small, nocturnal, scansorial geckos having a wide distribution throughout the Indo-Pacific region and Oceania, as far east as Hawaii (Zug 2010; Grismer et al. 2013; Cobos et al. 2016). Many new species have been described in recent years (e.g. Grismer et al. 2018a, 2018b, 2020; Sukprasert et al. 2018; Agarwal et al. 2019, 2020; Eliades et al. 2019; Nguyen et al. 2020; Zhang et al. 2020; Agung et al. 2021, 2022; Do et al. 2021). *Hemiphyllodactylus* generally have elongate bodies, widely splayed and expanded digits, and vestigial first digits on both hands and feet. They can be found in forested areas as well as on man-made structures (Grismer 2011a). The genus currently contains 52 species worldwide (Uetz et al. 2022), of which seven occur in Peninsular Malaysia: *H. bintik* Grismer, Wood, Anuar, Quah, Muin, Chan, Sumarli & Loredo, 2015; *H. cicak* Cobos, Grismer, Wood, Quah, Anuar & Muin, 2016; *H. harterti* (Werner, 1900); *H. larutensis* (Boulenger, 1900); *H. tehtarik* Grismer, Wood, Anuar, Muin, Quah, McGuire, Brown, Van Tri & Thai, 2013; *H. titiwangsaensis* Zug, 2010; and *H. typus* Bleeker, 1860. *Hemiphyllodactylus typus* is the only wide-ranging species of the genus found in Peninsular Malaysia, while others are endemic to specific upland localities (Zug 2010; Grismer 2011a; Grismer et al. 2013, 2015; Cobos et al. 2016). *Hemiphyllodactylus typus* is unisexual and widely distributed across the Indian and the Pacific Oceans, from Mascarene Islands and Sri Lanka, eastward through Indochina, Sundaland, and New Guinea, to the Hawaiian and Pitcairn

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Islands (Zug 2010; Grismer 2011a; Deso et al. 2020). Grismer (2011a) reported *H. typus* from seven localities in Peninsular Malaysia: Gunung Inas and Bukit Larut in the state of Perak (Grismer et al. 2010); Kepong, Selangor (Norsham et al. 2001); Tasik Chini, Pahang; Pulau Sibu, Johor (Wood et al. 2004; Grismer 2011b); Endau-Rompin, Johor (Wood et al. 2008); and Empangan Tembat, Terengganu (Chan 2010) (Fig. 1). The species is usually found on vegetation in mangrove, coastal, lowland, and hill dipterocarp forests (Grismer 2011a). New records of *H. typus* have been reported from several localities in Peninsular Malaysia since Grismer (2011a), and these include Grismer et al. (2013), Quah et al. (2013), Kaviarasu et al. (2014), Cobos et al. (2016), Davis et al. (2018), Badli-Sham et al. (2019), Zakaria et al. (2019), and Quah and Chua (2022). These records are compiled here along with some new records from recent field surveys, and we will discuss these new localities along with hypotheses of dispersal and colonisation in Peninsular Malaysia.

Methods

Specimen preservation and storage. Specimens were caught by hand during field surveys. Following euthanisation using Ethyl 3-aminobenzoate methanesulfonate ($C_9H_{11}NO_2 \cdot CH_4O_3S$), also known as Tricaine, liver samples were taken and stored in 100% ethanol. Specimens were then fixed in 10% formalin and later transferred into 70% ethanol for storage. Specimens not collected were identified based on photographic vouchers. Voucher material and photographs were deposited at the School of Biological Sciences, Universiti Sains Malaysia (specimen code USMHC). Specimen

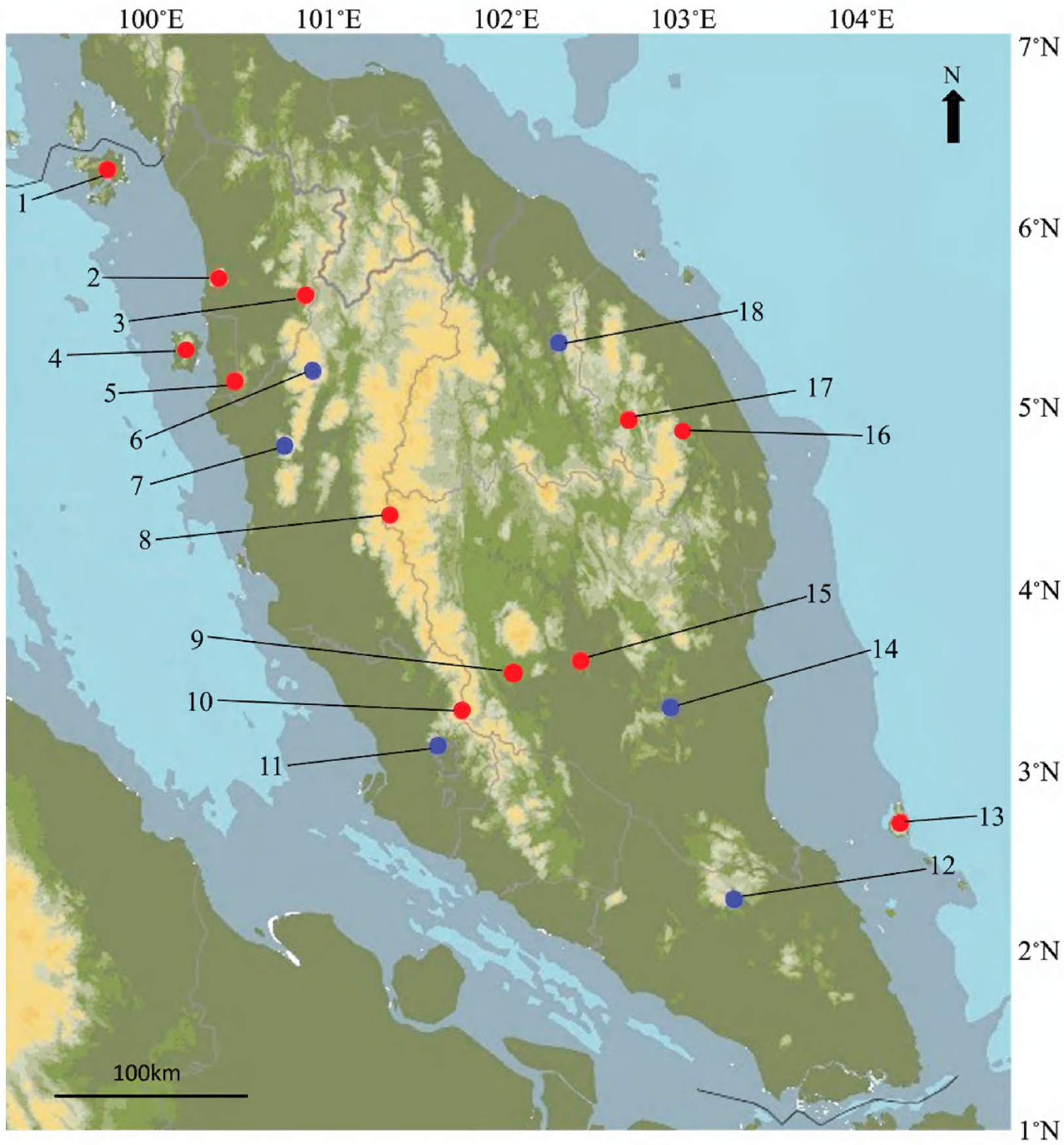

Figure 1. Map of Peninsular Malaysia showing the distribution of *Hemiphyllodactylus typus*. Blue dots are the localities reported in Grismer (2011a) and red dots are the updated localities. 1 = Gunung Raya, Langkawi, Kedah. 2 = Gunung Jerai, Kedah. 3 = Gunung Baling, Kedah. 4 = Penang Island. 5 = Bukit Panchor State Park, Penang. 6 = Gunung Inas, Perak. 7 = Bukit Larut, Perak. 8 = Cameron Highlands, Pahang. 9 = Krau Wildlife Reserve, Pahang. 10 = Genting Highlands, Pahang. 11 = Kepong, Selangor. 12 = Endau-Rompin, Johor. 13 = Pulau Tioman, Pahang. 14 = Tasik Chini, Pahang. 15 = Hutan Lipur Gunung Senyum, Pahang. 16 = Hutan Lipur Sekayu, Terengganu. 17 = Tasik Kenyir, Terengganu. 18 = Empangan Tembat, Terengganu.

collection was done with the permission of the Department of Wildlife and National Park, Peninsular Malaysia.

Morphological characters and identification. Morphometric and meristic data from the specimens were taken and additional diagnostic characters were recorded. These included snout-vent length (SVL), tail length (TL), trunk length (TrunkL), head length (HeadL), head width (HeadW), eye diameter (EyeD), snout–eye length (SnEye), nares–eye length (NarEye), internarial width (SnW); number of circumnasal scales (CN), intersupranasals scales (IS), supralabials (SL), infralabials (IL), chin scales (Chin), dorsal scale (DS: number of scales longitudinally at midbody on dorsum contained within one EyeD), ventral scale (VS: number of scales longitudinally at midbody on venter contained within one EyeD) lamellae beneath the first finger (FL1) and first toe (TL1), lamellar formula on forefoot and hindfoot (number of entire, U-shaped subdigital lamellae on enlarged pad of second to fifth digit, single apical lamella not counted, only large U-shaped lamellae touching edge of pad), total number of precloacal and femoral pores, number of cloacal spurs, and presence or absence of dark pigmentation in the oviduct and caecum. The identification of the specimens was confirmed by cross-referencing Zug (2010) and Grismer (2011a).

Results

***Hemiphyllodactylus typus* Bleeker, 1860**
Figure 2

New records. MALAYSIA – Terengganu • Hutan Lipur Sekayu; 04.9650°N, 102.9547°E; 191 m a.s.l.; 28.IX.2013; L. Lee Grismer obs.; on a large leaf in the parking lot – Kedah • Gunung Baling; 05.6850°N, 100.9126°E; 230 m a.s.l.; 13.VIII.2016; Evan S.H. Quah obs.; on the railing along hiking trail to the peak of the hill • Gunung Jerai; 05.7950°N, 100.4364°E; 960 m a.s.l.; 16.VIII.2019; Evan S.H. Quah obs.; on the wall of an abandoned building at night along the main road to the peak • Pulau Langkawi, Gunung Raya; 06.3690°N, 99.8186°E; 860 m a.s.l.; 21.VIII.2019; Evan S.H. Quah obs.; on a leaf along the wall of an abandoned building at night – Pahang • Cameron Highlands, Tanah Rata; 04.4704°N, 101.3784°E; 1440 m a.s.l.; 16.VII.2020; Evan S.H. Quah leg.; underneath the table of a coffee shop; 1♀, USMHC 2594 • Genting Highlands, Gohtong Jaya; 03.4069°N, 101.7617°E; 910 m a.s.l.; 25.I.2022; Hong Zijia leg.; on ferns at night along a trail by an abandoned road; 1 juvenile, USMHC 2781.

Identification. Adult specimen USMHC 2594 and juvenile specimen USMHC 2781 matched the descriptions by Zug (2010) and Grismer (2011a) in having vertical pupils; a thin and elongated trunk; head, body, limbs, and tail covered in granular scales; absence of tubercles; absence of enlarged postmental scales; no flaps of skin on the body; vestigial and clawless first finger and toe; transversely expanded pads with large, triangular, apical lamella bordered proximally by lyre-shaped lamellae; dark pigmentation in the caecum (Fig. 3); dark pigmentation in the oviducts of USMHC 2594 (Fig. 3); dusky tan to brown ground colour on dorsum; small, irregularly shaped dark markings on top of head; dark ocular stripe from the loreal region to the anterior section of the trunk; a series of conspicuous white post-orbital spots; dark, irregularly shaped, paravertebral markings extending from nape to base of the tail and

Figure 2. *Hemiphyllodactylus typus*. **A.** Gunung Raya, Langkawi, Kedah. **B.** Gunung Jerai, Kedah. **C.** Gunung Baling, Kedah. **D.** Cameron Highlands, Pahang (USMHC 2594). **E.** Hutan Lipur Sekayu, Terengganu. Photographs by Evan Quah (A–D) and L. Lee Grismer (E).

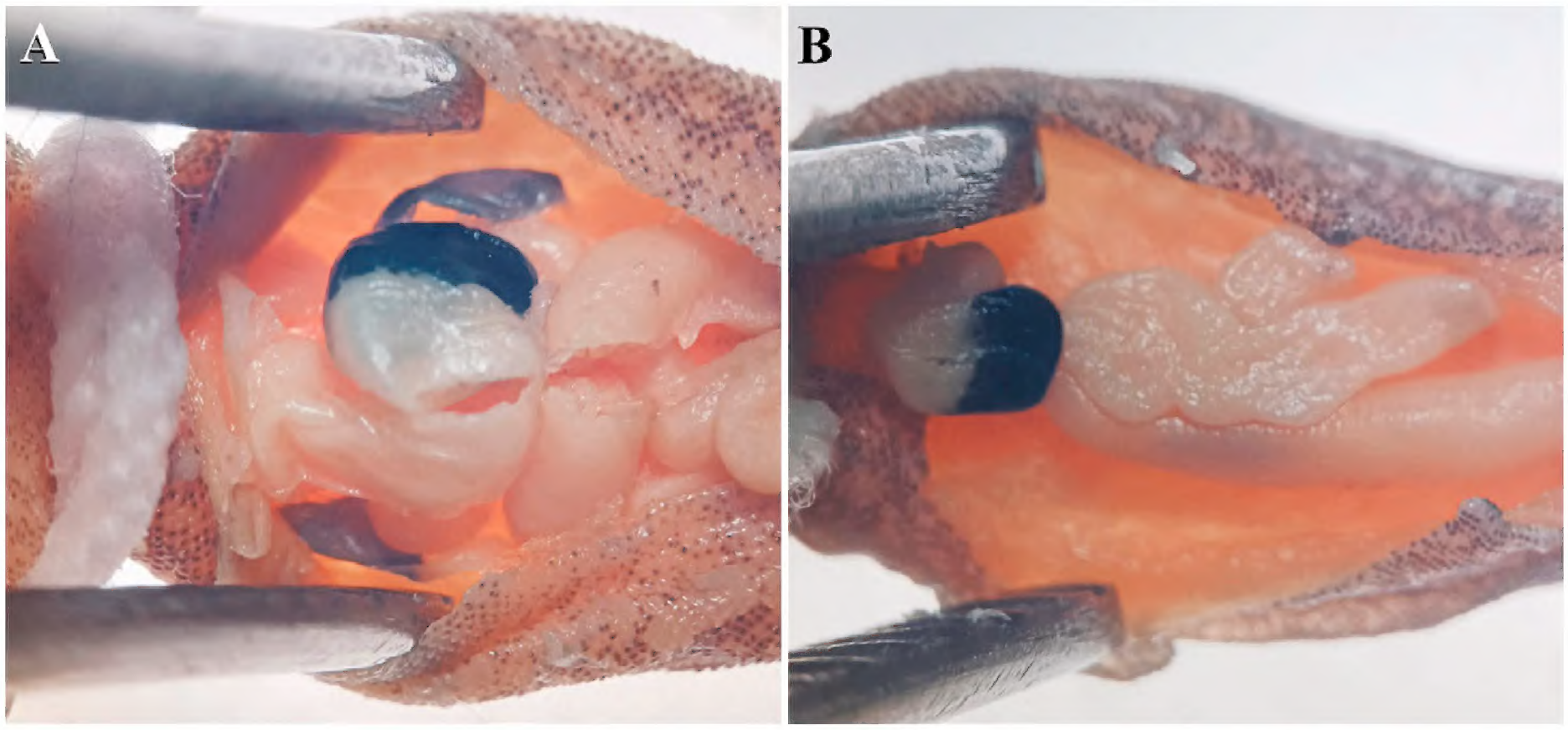

Figure 3. Pigmentation of *Hemiphyllodactylus typus*. **A.** Pigmented caecum and oviducts of USMHC 2594. **B.** Pigmented caecum of USMHC 2781. Photographs by Hong Zijia.

usually countershaded by smaller, orange to white spots; a dense, dark, U-shaped band at the base of the tail countershaded by a U-shaped, white to yellowish band; light-yellow to orange on dorsal surface of tail bearing irregularly shaped, dark, vertebral spots countershaded posteriorly by white markings; a dark, ventrolateral caudal stripe often present; chin to vent dusky in colour and pale yellowish orange on the underside of the tail.

Meristic data fall within the range of variation reported by Zug (2010) and Grismer (2011a): trunk length 13.19–19.57 mm; head length 6.23–8.97 mm; head width 4.30–5.30 mm; eye diameter 1.54–1.69 mm; snout–eye length 2.48–3.50 mm; nares–eye length 1.96–2.93 mm; internarial width 1.13–1.36 mm; five circumnasal scales; 1–3 intersupranasal scales; 12–14 supralabials; 11 infralabials; 12–14 chin scales;14–15 dorsal scales; 8–10 ventral scales; four rectangular lamellae on first finger; five rectangular lamellae on first toe; well-developed and clawed second to fifth fingers and toes; lamellar formulae on forefoot 3-4-4-4; lamellar formulae on hindfoot 4-4-5-4; one or two cloacal spurs and no precloacal or femoral pores (Table 1).

Similarly, the specimens photographed at Gunung Baling, Gunung Jerai, Gunung Raya and Hutan Lipur Sekayu were identified as *H. typus* based on their elongate body shape and colour pattern matching the description of this species given in the earlier paragraph (refer above).

Discussion

Hemiphyllodactylus typus was previously known from Gunung Inas, Bukit Larut, Kepong, Tasik Chini, Pulau Sibu, Endau-Rompin, and Empangan Tembat in Peninsular Malaysia (Norsham et al. 2001; Wood et al. 2004, 2008; Chan 2010; Grismer et al. 2010; Grismer 2011a, 2011b). According to Grismer et al. (2013), the only specimen of *H. typus* from Pulau Sibu is a male, and since *H. typus* is an all-female taxon, they have assigned the population from Pulau Sibu, Johor as *H.* sp. nov. 2. Hence, the occurrence of *H. typus* on Pulau Sibu is omitted here. Through a comprehensive review of the published literature, *H. typus* is found in six additional localities, which include Penang Island and Bukit Panchor State Park in the state of Penang, Krau Wildlife Reserve, Pulau Tioman and Hutan Lipur Gunung Senyum in the state of Pahang, and Tasik Kenyir in the state of Terengganu (Zug 2010; Grismer et al. 2013; Quah et al. 2013; Cobos et al. 2016; Davis et al. 2018; Badli-Sham et al. 2019; Zakaria et al. 2019; Quah and Chua 2022). In Penang Island, *H. typus* is found at Penang Hill, Air Terjun Titi Kerawang, and Tropical Spice Garden. Cobos et al. (2016) reported the presence of *H. typus* in the Ban Hin Lee Guest House at Penang Hill, where it occurs in syntopy with other gecko species, such as *H. cicak*, *Gehyra mutilata* (Wiegmann, 1834), *Gekko monarchus* (Schlegel, 1836), and *Hemidactylus frenatus* Duméril & Bibron, 1836. The presence of *H. typus* at Air Terjun Titi Kerawang is confirmed by a specimen used in the phylogenetic analysis of Grismer et al. (2013), while its presence at Tropical Spice Garden is reported by Quah and Chua (2022). At Krau Wildlife Reserve, the present of the species is confirmed by a specimen examined in Zug (2010). According to the database of the Museum of Comparative Zoology, Harvard University (2022), the specimen was collected at a ranger post at Kuala Lompat in Krau Wildlife Reserve. Together with the six new records, *H. typus* is now known from 18 localities in Peninsular Malaysia.

Hemiphyllodactylus typus occupies a wide range of habitats in Peninsular Malaysia, including lowland and hill dipterocarp forests, swamps and anthropogenically modified habitats, up to an elevation of 1440 m. In natural habitats such as forest, it is usually observed crawling on vegetation at night (Grismer 2011a; Quah

Table 1. Morphological characters of *Hemiphyllodactylus typus* by Zug (2010) and Grismer (2011a), and specimens from Cameron Highlands and Genting Highlands, Pahang. (—: data not available.)

Characteristics	Zug (2010)	Grismer (2011a)	USMHC 2594 Cameron Highlands	USMHC 2781 Genting Highlands
Snout–vent length (SVL)	29.4–46.1 mm	Reaching 48 mm	38 mm	28 mm
Tail length (TL)	14–36 mm	~0.8 times SVL	16 mm	21 mm
Trunk length (TrunkL)	15.0–28.0 mm	—	19.57 mm	13.19 mm
Head length (HeadL)	6.6–9.9 mm	—	8.97 mm	6.23 mm
Head width (HeadW)	3.7–6.6 mm	—	5.30 mm	4.30 mm
Eye diameter (EyeD)	1.5–2.4 mm	—	1.69 mm	1.54 mm
Snout–eye length (SnEye)	2.3–4.1 mm	—	3.50 mm	2.48 mm
Nares–eye length (NarEye)	1.8–3.4 mm	—	2.93 mm	1.96 mm
Internarial width (SnW)	0.9–1.7 mm	—	1.36 mm	1.13 mm
Number of circumnasal scales (CN)	1–5	—	5	5
Number of intersupranasals scales (IS)	1–5	—	3	1
Number of supralabials (SL)	9–14	8–13	12	14
Number of infralabials (IL)	7–13	8–12	11	11
Number of chin scales (Chin)	9–14	—	14	12
Dorsal scale (DS)	12–19	—	14	15
Ventral scale (VS)	8–14	—	8	10
Number of lamellae beneath first finger (FL1)	4–5	—	4	4
Number of lamellae beneath first toe (TL1)	5–6	—	5	5
Lamellar formulae on forefoot	3-4-4-4	—	3-4-4-4	3-4-4-4
Lamellar formulae on hindfoot	4-4-5-4	—	4-4-5-4	4-4-5-4
Total number of precloacal and femoral pores	0–26	15–19	0	0
Number of cloacal spurs	1–5	—	2	1
Oviduct pigmented (1) or not (0)	1	—	1	0
Caecum pigmented (1) or not (0)	1	—	1	1

et al. 2013; Davis et al. 2018; Badli-Sham et al. 2019; this study). This species will also utilise man-made structures when the opportunity arises and can be found both outside and inside buildings (Cobos et al. 2016; pers. obs.). These geckos possibly seek shelter in the buildings to avoid the unfavourable weather or to forage for insect prey that are attracted to artificial lights. The observations of *H. typus* on man-made structures at various locations and different elevations across Peninsular Malaysia, such as the Cameron Highlands, Penang Hill and Krau Wildlife Reserve, highlight the adaptability of this species in utilizing anthropogenically modified habitats. The wide geographical range of *H. typus* across the Indian and Pacific Oceans is also hypothesised to be a result of human transportation through shipping networks, especially during the British colonisation era in the past two centuries (Zug 2010; Jayaneththi and Jablonski 2016; Deso et al. 2020). Since Cameron Highlands, Penang Hill and Krau Wildlife Reserve were established by the British during the colonisation period, *H. typus* might have also been accidentally introduced there (Aiken 1987; Weebers and Idris 2016; Guérin 2018). Accidental transportation of *H. typus* has also been observed in recent years. In Sri Lanka, *H. typus* was observed in nursery plants that were transported from one location to another (Jayaneththi and Jablonski 2016). Besides that, the presence of *H. typus* in Ryukyu Archipelago of Japan is also hypothesised to be accidental introduction through the imports of coconut palms from Southeast Asia, where the species has been observed in the space between the trunk and the leaf sheath of a coconut palm around housing area (Ota 1990).

The small body size of *H. typus* (SVL 29.4–48.0 mm) and its small eggs (5.5–8.2 mm) allow it to utilise various types of microhabitats, including some that are difficult to be accessed by other larger species (Zug 2010; Grismer 2011a; Fisher et al. 2013; Holden et al. 2014; Deso et al. 2020). For example, at Bako National Park in Sarawak, adults of *H. typus* and eggs were observed in the empty ant-leaves of a myrmecophilous plant, *Dischidia rafflesiana* (Vahl) Merr. (Janzen 1974). In some other areas, *H. typus* was also observed from *Asplenium* L. ferns in the upper canopy of primary rainforest and in metallic road signs away from human settlements (Deso et al. 2008; Donald et al. 2017). The high adaptability of *H. typus* in different environments and its ability to reproduce through parthenogenesis might also be the reason for its worldwide distribution (Deso et al. 2020). Although *H. typus* is a widespread species, it is often quite difficult to find. This might be due to its small size, strictly nocturnal lifestyle and cryptic colouration (Grismer 2011a; Jayaneththi and Jablonski 2016). *Hemiphyllodactylus typus* will likely be found from

more localities in Peninsular Malaysia with additional field surveys.

Finally, other studies have suggested that *H. typus* is a species complex, where populations from Indonesia and the Pacific and Indian Oceans might represent different species, and population genetics analysis should be conducted to resolve this (Deso et al. 2020). Likewise, the specimens reported from around Peninsular Malaysia in the present study represent putative species assignments that warrant genetic testing in the future that is not part of the scope of this present report.

Acknowledgements

We express our gratitude to the Department of Wildlife and National Parks, Peninsular Malaysia and Majlis Biodiversiti Pahang for issuing us research permits (JPHL&TN(IP): 100-34/1.24 Jld 14 (71) and MBP.600(S)-1/1/1(6)) to conduct research. We also thank the staff from School of Biological Sciences, Universiti Sains Malaysia, Perry L. Wood Jr. for his valuable insight, and everyone else who were involved in the study for their assistance. Besides that, we would also like to thank Ade Prasetyo Agung, Jesse Grismer, and Perry L. Wood Jr. for reviewing the manuscript and providing us with valuable comments that improved its quality. The study was supported by the Fundamental Research Grant Scheme of the Ministry of Higher Education (FRGS/1/2019/WAB13/USM/01/1).

Author Contributions

Conceptualization: ESHQ. Formal analysis: ZH. Funding acquisition: SA. Investigation: LLG, BZ, ZH, ESHQ. Methodology: LLG. Project administration: SA. Supervision: SA, ESHQ. Validation: LLG. Visualization: ZH. Writing – original draft: ZH, ESHQ. Writing – review and editing: BZ, ESHQ, LLG, SA.

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